First Identification of ^{178}Pb

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Studies of nuclei near the proton drip-line may reveal their existence, masses, half-lives, decay modes and structure. Such information is critical for testing various theoretical nuclear models and helps to elucidate the evolution of the mass surface, structure and shell effects as one moves toward the extreme limits of nuclear stability.

The decay of ^{178}Pb, 26 neutrons removed from the lightest stable isotope, has been measured for the first time. Prior to this experiment, the lightest known lead isotope was ^{180}Pb [1]. To produce ^{178}Pb, a 90% enriched 1.02 mg/cm^2 target of ^{102}Pd was bombarded by a 340 MeV (mid-target) beam of ^{78}Kr ions at the 88-Inch Cyclotron. Fusion-evaporation residues were separated from the primary beam by the Berkeley Gas-filled Separator (BGS), passed through two parallel-plate avalanche counters (PPAC's) and were implanted into a position-sensitive silicon strip detector. Chains of known alpha decays observed from the same position on the detector shortly after implantation (<20 s) permitted the reaction products to be positively identified by comparing the energies of the alpha particles to values in the literature. By recording the time intervals between decays, half-lives were also deduced.

Two atoms of ^{178}Pb were identified by correlation with the known decays of the ^{174}Hg daughter [2] or ^{170}Pt grand-daughter [3]. In Table 1, the observed decay chains are compared to values in the literature. Based on the alpha decay spectrum and event rate observed during the experiment, the random chance of observing two 7.25 - 8.0 MeV alpha decays with decay times shorter than 0.5 s and an energy difference of < 70 keV (twice the resolution of the detector) is calculated to be 1 in 156. Furthermore, the chance of observing an alpha decay of any energy randomly correlated to a 7066 ±35 keV ^{174}Hg alpha decay within 23 ms (ten times the upper limit on the ^{174}Hg half-life measurement [2]) is estimated at 1 in 2500.

Based on the energy of this decay, the mass excess of ^{178}Pb is 3609 ±37 keV, in closest agreement with the Finite-Range Droplet Model prediction [4] of 3430 keV. The production cross section was about 20 pb. Using a maximum-likelihood approach and the observed decay times, the calculated half-life is $121\ ^{+220}_{-48}$ μs. A reduced width of $46\ ^{+110}_{-20}$ keV is calculated for the decay. Although the magnitude of the error bars prohibits a definitive conclusion, this suggests that the trend of slowly decreasing reduced widths [1], starting with ^{186}Pb at the middle of the neutron shell, continues with ^{178}Pb.

TABLE 1: Comparison of observed alpha decay chains to literature values. The half-lives of the isotopes are indicated in the literature column, while observed decay times are indicated for the two chains.

Isotope	Literature	Chain #1	Chain #2
^{178}Pb	(unknown)	7602 keV	7629 keV
		202 μs	147 μs
^{174}Hg	7066 keV	7065 keV	(escape)
	$1.9\ ^{+0.4}_{-0.3}$ ms	1.1 ms	–
^{170}Pt	6545 keV	6570 keV	6560 keV
	$15\ ^{+16}_{-6}$ ms, $6\ ^{+5}_{-2}$ ms	7.8 ms	86 ms

Footnotes and References

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